Effects on Training Using Illumination In Virtual Environments

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1 Introduction

Camera based tasks are commonly performed during orbital operations, and orbital lighting conditions, such as high contrast shadowing and glare, are a factor in performance. Computer based training using virtual environments is a common tool used to make and keep crew members proficient. If computer based training included some of these harsh lighting conditions, would the crew increase their proficiency?

The project goal was to determine whether computer based training increases proficiency if one trains for a camera based task using computer generated virtual environments with enhanced lighting conditions such as shadows and glare rather than color shaded computer images normally used in simulators.

Previous experiments were conducted using a two degree of freedom docking system. Test subjects had to align a bore sight camera using a hand controller with one axis of rotation and one axis of translation. Two sets of subjects were trained on two computer simulations using computer generated virtual environments, one with lighting, and one without. Results revealed that when subjects were constrained by time and accuracy, those who trained with simulated lighting conditions performed significantly better than those who did not. To reinforce these results for speed and accuracy, the task complexity was increased.

This paper covers the third, in a series of experiments, conducted in the second year of an NRA 95-OLSMA-01 funded project entitled "Human Task Performance Evaluation With Luminance Images". For this phase of the project, subjects trained for a docking operation involving five degrees of freedom. In addition, the docking operation required maneuvering along a series of three dimensional paths as opposed to the simple alignment operation in the

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Twenty test subjects were trained to perform the maneuvering and docking task using a computer generated environment. Half of the subjects trained with color shaded color images, the other half trained on lighting enhanced color images using features such as shadows, glare and light reflection. After having docked four consecutive times in their training phase, all the subjects were tested using the same maneuvering and docking hardware with identical real lighting conditions.

The docking hardware and its computer-generated counterpart consists of a movable camera mounted onto a computer controlled translation table. With a hand-controller, the movable camera (docking camera), can be panned left and right, and tilted up and down. The same hand-controller also controls the camera's three translation motions: two in the horizontal plane and one in the vertical. To view the docking-camera from different perspectives, two stationary, immovable cameras that view the docking procedure from different angles, were placed around the configuration.

The test subjects were seated in front of a monitor which displayed computer generated images for the training phase. Subjects also used the same interface arrangement for the test phase except the monitor images were live video from real cameras. The subjects began their training-phase by observing an animation of the docking procedure. The test administrator then demonstrated the docking procedure using the hand controller. After having learned how to use the hand controller, the subjects practiced the docking operation. First, they toggled between the two stationary cameras to find the circular docking target that is mounted on a wall near the translation table. Next, the subjects moved and aligned the docking camera to the target, and finally closed in on the target until they were docked.

After the test subjects had docked successfully once with the aid of the test administrator, they were asked to dock four consecutive times or a maximum of seven times, whichever came first, as fast as possible and without the help of the test administrator. Half of the test subjects trained with lighting enhanced computer generated images, the other half used conventionally shaded images (Figures 1 and 2). As an added difficulty, the starting position of the docking

camera and the target varied randomly for each session. Only subjects who docked at least four times were considered trained and, hence, used for the statistical analysis.
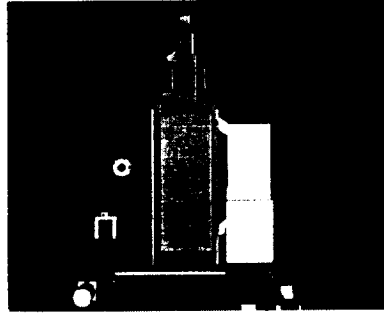

Figure 1. Conventional Color Shading

Figure 2. Image with Lighting

In the test phase, all subjects performed the same docking process with real lighting conditions; the setup of the main-frame was kept the same. Again, they were asked to dock as fast as possible. In addition, test subjects were asked to fill out a post-test questionnaire at the end of the test.

2 Methodology

In the previous experiments for this project, a translation and rotation table configuration was used. To increase the degrees of freedom required for this phase, two additional translation tables were added to the configuration and a camera pan-tilt unit replaced the rotation table. This hardware along with two additional fixed cameras, lighting, a monitor, a hand controller and the appropriate controller software with collision detection constituted the operational task environment for which the subjects were to be trained.

To train the subjects, a virtual model of the operational environment needed to be created. Primitive or base components were modeled using a commercial computer aided design (CAD) system (Pro Engineer) and assembled using an in-house developed Computer Aided Engineering (CAE) tool called PLAID to create the virtual task scenario of translation tables, cameras, lights and a pan-tilt unit with the appropriate articulations, rotation and translation limits as well as collision detection. To further replicate the "real world" in the virtual world, hand controller responsiveness as well as the rotational and translational velocities were matched to the hardware counterparts.

Script files were authored to provide sequence variation for test sessions. When executed, these scripts randomly generated different lighting conditions as well as different target locations and initial positions for the translation table and

camera pan-tilt unit for each training session. The computer-generated lighting effects where created with the aid of a ray-tracing software called Radiance. After having rendered images in Radiance, the shadows were replicated in the training software.

Before testing, subjects were provided written instructions and a demonstration.

3 Results

In contrast to the previous experiments, test subjects in this study experienced a learning curve. Before subjects could perform the docking process, they had to spend time learning to select from the available view points for orientation as well as learning the use of the hand controller for maneuvering around the obstacles with a minimum of collisions. One of the requirements for training was the ability to dock at least four times during the training period. Though arbitrary on our part, this requirement served as an objective test for measuring a basic skill required for the experiment. However, out of twenty-five subjects, nine subjects were disqualified because they could not dock at least four times. Upon reflection, this filter, though necessary, may have been too strict, because the number of subjects was reduced to sixteen, eight for each group, thus reducing our subject base below what we would have otherwise desired. This did reduce the impact of the statistics somewhat. However, the trends that were detected appeared to be quite clear and provided a degree of confidence despite the lower than expected subject count.

3.1 Time Test

Users were timed when executing the test of maneuvering and docking the flight camera with a hand controller. Subjects trained with lighting performed the docking operation at least ten percent faster that those subjects who trained without it. Average times were 294.86 and 324.33 seconds.

3.2 Collisions

While subjects were maneuvering the flight camera using the hand controller, the controller software tracked the camera's position along the three dimensional path required to reach the docking target. Using this positioning information as well as the explicit mathematical definition of the path boundary, collisions with the boundary were detected. This was detectable for both test and training phases although only the statistics for the test phase were analyzed. The results were dramatic. Collisions were detected for five out of eight subjects (62.5%) trained without lighting. Collisions were detected for only one out of eight subjects (12.5%) trained with lighting. This statistic would indicate that subjects trained with lighting are accurate overall in the execution of the task not just in the docking phase. Though the subject count is small, the trend

is very distinct. These findings clearly warrant an examination of additional subjects.

3.3 Subjective Results

Subjects completed a questionnaire at the end of the test. All subjects thought training to be useful, all but one thought lighting important to training, and those who trained with lighting thought the task was easier to do than those who did not train with lighting.

4 Conclusions

The results of this experiment further validate the theory that one can train for camera-based tasks more effectively when realistic lighting is incorporated into the training. The task of testing subjects for a more complicated task was achieved for this phase of the project, and the difference in the docking times supports the findings of the first two experiments. The relatively low statistical significance of ninety percent indicates that the testing needs refinement. Finally, additional subject testing would also be desirable.

5 References

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